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SYNOPSIS OF BIOLOGICAL DATA

ON THE PIKE

Esox lucius Linnaeus 1758

Prepared by

E.D. Toner

Department of Lands, Fisheries Division
Dublin, Ireland

for

European Inland Fisheries
Advisory Commission (EIFAC)

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Synopsis of biological data on the pike Esox lucius Linnaeus 1758

Reviews information on identity, distribution, bionomics, and life history, population and exploitation in Europe and other continents. Incl. a comprehensive bibliography.

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1 IDENTITY

1.1 Taxonomy

1.1.1 Definition

Phylum VERTEBRATA
Subphylum Craniata
Superclass Gnathostomata
Series Pisces
Class Teleostomi
Subclass Actinopterygii
Order Clupeiformes
Suborder Esocoidei
Superfamily Esocoidea
Family Esocidae
Genus Esox
Species Esox lucius

1.1.2 Description

Genus ESOX

"Body elongate, head large, with snout strongly produced forward and flattened. Mouth very large, occupying one half of head, Lower jaw prominent, mandibular joint behind posterior margin of eye. Teeth on premaxillaries, vomer, palatines, lower jaw, and tongue. Teeth strong, of varying size on lower jaw. Maxillary with a supplemental bone. Branchiostegal membranes not coalescing, free from isthmus. Gill rakers tuberculiform. Pectoral fins with 1,11 - 16 rays, inserted very low. Ventrals behind pectorals, with 1,11 - 1. 12 rays. Stomach without blind sac and without pyloric caeca. Branchiostegals 11 - 20. Head naked or scaled dorsally; cheeks and opercular bones partly scaled. Dorsal fin set far back, above anal, with 10 - 17 branched rays. Anal with 10 - 16 branched rays. Caudal fin emarginate, with 19 developed rays. Scales small, 105 - 156 in the lateral line; lateral line absent or incomplete in the young, complete in adults. Premaxillaries not in contact. Vertebrae not elongate; vertebral count in recent species 56 - 65. Myodome, basisphenoid, postcleithrum, octopterygoid, nasal bone present. No inframandibulars. Olfactory nerve passing through orbit" (Berg, 1962).

Esox lucius Linaeus, 1758

(Figure 1)

"Length of head 3½ to 4, of caudal fin 6, height of body 6½ to 7 in the total length. Eyes - situated in about the middle of the head, the diameter of each 7 to 12 in the length of the head, 4 to 6 diameters from the end of the snout, 1½ to 2 apart. The dorsal and abdominal profiles nearly horizontal and parallel, causing the body to be of almost equal height from the head to the commencement of the dorsal and anal fins: its head flattened above, while its length is equal to nearly twice that of the height of the body. Cleft of mouth very deep, equalling about half the length of the head: lower jaw a little longer. The middle of the upper jaw is slightly emarginate, and receives the head of the vomer; on either side of the short premaxillaries, which are not nearly so long as the maxilla, which is composed of two pieces, is capable of a considerable amount of motion, and reaches posteriorly to beneath the front edge of the eye. Nostrils large, and nearer the orbit than the end of the snout. Numerous glandular orifices on the head. Teeth - none on the maxillary: large ones and of unequal size on the mandibles: present on the vomer and palatines, the inner row of which are the larger, more or less strong and depressible: also fine ones on the tongue. Fins - the dorsal is situated in the last fourth of the standard length, and slightly in advance of the origin of the anal. Pectoral placed low down and below the subopercle. The ventral slightly behind the middle of the standard length. Caudal emarginate or slightly forked. Scales - small, present on the cheeks, upper portion of the opercle, and over the body. Lateral line - nearly straight. Colours - when in the greatest perfection of a green colour, becoming lighter on the sides and beneath: numerous yellow blotches, spots and bands of dark. When out of season the green becomes of a grey, and the yellow markings pale or white." (Day, 1880-1884)

1.2 Nomenclature

1.2.1 Valid scientific name

Esox lucius Linnaeus

1.2.2 Synonyms

There are no synonyms but Day (1880-1884) mentions "Lucius arboreus, Agassiz, Lake Superior, p.317." without further explanation.

1.2.3 Standard common names, vernacular names

See Table I

1.3 General variability

1.3.1 Subspecific fragmentation (races, varieties, hybrids)

No separate races; hybrids and mutants only.

Hybrids: McCarraher (1960) describes four naturally occurring specimens of a cross between Esox lucius and E. americanus from Nebraska and Schwartz (1962) has made artificial crosses between the same two species which he compares with McCarraher's fish. Black and Lyman (1947) have crossed Esox masquinongy and E.lucius and Underhill and Heaton (1939) have crossed E. lucius and E. niger.

Mutants:
Lawler (1960) found that a so-called "silver pike", a variant, in colour and in some morphometric measurements, made up 0.2 percent of a normal lake population in Manitoba.

Table I
Standard common names, vernacular names

Country	Standard common names	Vernacular names
England	Pike (from Saxon piik meaning sharp-pointed)	Hacod (Anglo Saxon)
Scotland		Gedd or Gade Morris (a large pike); frie (a very young pike); picche or pod
Wales		Penhwyaden
Ireland	Pike; jack (a small pike)	Lius (loose), gailliasc (golleesc) grosan, gedas (Farran, 1946)
Holland	Snoek	
France	Brochet; brocheton, (a small pike)	Lance or laceron (reference to speed); becquet (reference to duck-billed shape of snout viewed from above)
Spain	Lucio	
Germany	Hecht	
Sweden	Gädda	
Denmark and Norway	Gedda	
Austria	Hecht	
Italy	Luccio	
Switzerland	Brochet, hecht and luccio	
Russia	Shtchuka	
Poland	Szczupak	
U.S.A.	Northern pike	Pike, grass pike, jack-pike, jackfish, jack snake, common pike, pickerel, ke-no-shay (Berg, 1940, Wistrom et al, 1957), grass pickerel, silver pike, shovelnose, lake and spotted pickerel, laker, great pike, great lakes pike, great northern pickerel, lake pike.(Clark, 1958)
Canada	Northern pike	Channel pickerel, Canada pike, slinker, shovelnose pike, short pickerel, marsh pickerel, jackfish. (Clark, 1958).

2 DISTRIBUTION

2.1 Delimitation of the total area of distribution and ecological characterization of this area (Figure 2)

The Esocidae are restricted to the cold and temperate parts of the northern hemisphere, holarctic in distribution including most of the north temperate zone above 40° latitude and penetrating into the Arctic zone. From Alaska and Siberia south to Missouri, the Ohio River and New York in the U.S.A. and to Italy and Greece in Europe (Clark, 1958). The pike has been introduced by man to localities and countries in which it did not naturally occur within this general range; e.g., Spain (see under 5. 6). Remains of Esox have been found in various fresh water deposits in Europe as far back as the Oligocene. E. lepidotus, of which very perfect specimens have been found in the Upper Miocene bed of Oeningen in Baden, differs from the living species in its much larger scales and in the greater approximation of the ventral and anal fins, two characters in which it approaches Umbra (Harmer and Shipley, 1910). The fossil remains would seem to indicate that the origin of the family was in Southern Europe although most of the living species are American (Jordan, 1905). Threinen and Oehmcke (1950) hold that E. lucius is a more recently evolved species than E. masquinongy.

2.2 Differential distribution

2.2.1 Areas occupied by eggs, larvae and other junior stages: annual variations in these patterns, and seasonal variations for stages persisting over two or more seasons

Eggs are found in marshy areas of lakes and streams or in connected sloughs. The prolarva and presumably the eggs also are most abundant in Carex and Eliocharis. Emigration of alevins to open water begins when the fish attain 20 millimeters in size (Franklin and Smith, 1963). In Irish investigations in 1965 (Kennedy, unpublished) pike eggs were found on broken reed mat (Phragmites); on a mud bottom in sheltered situations (L. Arrow); on moss Fontinalis (L. Sheelin); and on grassy bottoms, covered with Agrostis stolonifera and Juncus bulbosus, var. fluitans mixed with patches of Mentha aquatica, Hippuris vulgaris and other weeds (L. Mask and L. Corrib). The spawning sites were mainly at depths of 15 to 30 inches.

2.2.2 Areas occupied by adults

Typically in clear lakes and streams with weedy bottoms and margins but also in turbid waters. In shallows in spring and summer, in deeper waters in late summer with a gradual return to shallows as winter approaches (Clark, 1958). Zawisza (1963): Confined to littoral zone; older specimens in deeper waters. Most abundant in shallow lakes (maximum depth about 4 metres), rich in vegetation, with clear water. Larsen (1945 and 1951): Acid lakes, clear lakes, peat and marl pits are suitable but turbid lakes are not and pike-perch should be substituted in such waters. Greene (1935) gives a similar description of typical localities for Wisconsin, but Eddy and Surber (1947) say: "This species is found in nearly all the streams and lakes of Minnesota. It prefers sluggish streams and seems to be fond of the warm, muddy waters of shallow, weedy lakes, but is equally abundant in most of the cold, clear waters of the deep, rocky waters of the north".

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.1.1 Sexuality (hermaphroditism, heterosexuality, intersexuality)

The pike is heterosexual; no cases of hermaphroditism are known to the author, but Fabricius and Gustafson (1958) report the occurrence of homosexual behaviour during spawning.

3.1.2 Maturity (age and size)

The following records are from the U.S.A. and Canada. In Wisconsin, males mature at 2 years and a length of 37.6 - 45.7 cm. In southern Wisconsin some females mature at 2 years and at about 50.8 cm, but more generally at 3 years and at the same length (Scott, 1954). Miller and Kennedy (1948) record 5-6 years of age at first maturity for fish from Great Bear Lake while Rawson (1932) puts it at 3-5 in Lake Waskesiu, Saskatchewan. Sell (1952) says that the majority of pike in Minnesota mature after their third year, and Bean (1902) says New York pike are 5 years of age before becoming ripe. Rawson (1932) reports that some but not all females spawn at the end of their third year and few, if any, males mature until the end of their fourth year.

In Ireland, Healy (1956) found that in Barnagrow Lough where the rate of growth was slow, only 2 percent of the males were mature at 12 months from hatching and only 11 percent of the females were mature at 24 months from hatching. In Lough Glore, where the growth rate was more rapid she found, however, that 74 percent of the males were mature at 12 months from hatching and 70 percent of the females were mature at 24 months from hatching. Investigations in 1964-65 in four other Irish lakes, L. Arrow, L. Mask, L. Corrib and L. Sheelin, where the growth rate was also rapid, indicated that the majority of the males were mature at a year old and the majority of the females at 2 years old (Kennedy, unpublished). In England, Hartley (1947) records that the youngest spawning pike he examined were 3 year old females, the smallest being 29.5 cm. long. In Lake Windermere, Frost and Kipling (1964) found that 92.5 percent of females were sexually mature when just over 2 years of age and had an average length of 41.5 cm. 2.5 percent were mature at 1 plus and 5 percent at 3 plus years. Of the males: 80 percent were mature when just over 2 years with an average length of 38 cm; 5 percent at 1 plus and 15 percent at 3 plus years of age. In Scotland, Munro (1957) reports that no fish (in Loch Choin) in the 0 plus and 1 plus groups were ripe but all in the 3 plus and older groups were mature except one 3 plus male. In the 2 plus group 40 percent of males and 37.1 percent of females were maturing fish. The smallest maturing male was 26.3 cm. and the smallest maturing female was 25.7 cm.

Clark (personal communication) records that out of 93 1-year old hatchery pike, 12 showed signs of maturity; only one of these was a female from which the eggs flowed on handling. The same author (1958) found that about half the hatchery reared pike produced at 2 years of age.

From Spain, Calderon-Andreau (1955) reported that very fast growing pike, imported from France as ova, were sexually mature at the end of their first year of life. Fedin (1958) reports sexual maturity at one year under suitable conditions.

3.1.3 Mating (monogamous, polygamous, promiscuous)

Certainly polygamous and promiscuous. Zawisza (1963) says each female is accompanied by a few males on to the spawning grounds. Rawson (1932) reports that males and females were about equal in number in spawning runs but Clark (1950) says that while males predominated in the early spawning movements females were more numerous later on; Carbine records that males were more numerous than females. Healy (1956) states that the males moved on to the spawning areas before the females.

3.1.4 Fertilization (internal, external)

External. Lindroth (1947): The micropyle closes after 0.5 to one minute after emission.

3.1.5 Fecundity

Vessel and Eddy (1941), record that a 76.2 cm pike and a 53.3 pike contained respectively 100,000 and 31,000 ova. Healy (1956) suggests that the number of ova per unit body weight increases with age and the weight of the fish. Nikolsky (1963) gives the fecundity of the pike of length 30-45 cm in the Aral Sea as being 8,287 eggs and in the North Caspian as 17,581. Frost and Kipling (1964) find that the number of eggs per unit body weight does not increase with the size of the fish and Berg (1962) records considerable differences in fecundity between pike in different waters.

Table II
Relation of gonad size and egg number to body size and to age

Author	Range per kg	Av. no. per kg	Remarks
Healy (1956)	19,600-41,800 15,800-39,100	28,100) 22,500)	Gravimetric estimates on 53 fish
Pincher (1947)	21,400-40,900	35,200	Actual counts of 4 ovaries
Frost and Kipling (1964)	22,000-41,000	32,000	Based on counts of parts of ovaries from 30 fish
Zawisza (1963)		27,000	
Otterstrom (1941) For fish over 5 kg		17,919	
For fish of 2-5 kg		23,472	
Carbine (1944)	7.691-97,273	35,200	Figures for individual fish; lengths or wts. not given

3.1.6. Spawning

- Spawning seasons (beginning, end, peak)

Table III
Spawning season for various localities

Locality	Beginning	End	Authority & Remarks
U.S.S.R. (Ukraine)	20 February	20 April	Fedin (1958)
Saskatchewan	1 May	15 May	Rawson (1932)
Ohio	28 March	8 April	Clark (1950)
Michigan	2 April	25 April	Carbine (1942)
L. Windermere, England	Mid-March	Late May	Frost and Kipling (1964)
Minnesota	1 April	27 April	Dobie (personal communication)
New York	March and	April	Adams & Hankinson (1928)
Ireland	February	April	Healy (1956)
Denmark (a)	Late May	Early June	Larsen (1944); in water of 8 promill salinity
Denmark (b)	April	April	Larsen (1944); in fresh water
Poland	Earliest Latest	26 March 1957 28 April 1958.	2 June, Zawisza (1963)

Generally the season extends from February to May in all parts of its range. Some spawning seasons are given above

- Number of spawnings per year, frequency

Each individual of both sexes performs the spawning act only once annually

- Spawning time of day

During the hours of daylight both in captivity (Fabricius and Gustafson, 1958), and in the wild (Svärdson, 1948). At Lake George, Minnesota, spawning was observed only between 1400 hours and 18.00 hours (Franklin and Smith, 1963). Clark (1950) states that spawning groups were seen at 6.00 hours Eastern Standard Time and as late as 18.30 hours, but none were noted at night. Cloudy days, he says, seemed to retard spawning activity and cool nights seemed to delay spawning on the following morning.

- Induction of spawning, artificial fertilization

Injections of pituitary extract from carp used in Iowa are credited with being responsible for a 97 percent ripening of females (Johnson, 1960). Clark says carp pituitary and chorionic gonatropin have been used with varying degrees of success (personal communication, 1964).

- Hydrographic conditions for spawning

Table IV
Spawning temperatures recorded in various localities

Locality	Water Temperature (°C)	Authority and remarks
Saskatchewan	13.0	Rawson (1932)
Ontario	9.4 - 14.4	McKay (1931)
Ohio	9.9	Clark (1950)
Minnesota	6.7	Bennet (1948)
Minnesota	11.0 - 17.0	Franklin and Smith (1963)
Poland, near shore	2 - 4	Zawisza (1963)
deeper	4 app.	
Ireland	10 - 11	Kennedy (unpublished)

Releasers for spawning are apparently the lengthening diurnal cycle, water temperature and the flooding of marsh vegetation, though spawning will take place at low water level (Svärdson, 1948). High temperature and intense light stimulate natural spawning (Fabricius and Gustafson, 1958). Spawning depth: 0.3-1.2 metres (Fedin, 1958); Zawisza (1963) 4-7 metres. Zawisza (1963) also records that near shore spawning coincides with the beginning of the blooming of Tussilago farfara and full blooming of Petasites officinalis. The late spawning on mid-lake shoals coincides with the beginning of blooming of Caltha palustria.

3.1.7 Spawning grounds

The eggs are well scattered on dense, short vegetation (Fabricius and Gustafson, 1958). Flooded marsh vegetation (Svärdson, 1948). Zawisza (1963) described inshore spawning as occurring in the shallow littoral zone protected from the wind and in flat meadows covered by spring flood waters. The usual substrata are old leaves or trees, Carex, Iris, Agrostis alba. Later the deeper spawning takes place on Elodea canadensis. Healy (1956) ".....in the reeds in very shallow water.....The temperature and the level of the water.....seem to be two important factors which determine the time of spawning. Many females have been netted in May and June, when the level of the lakes was very low, which were still full of spawn". Frost and Kipling (1964) say that spawning takes place in Windermere in water to 8 feet deep on Elodea and Myriophyllum. van Drimmelen (1950) emphasises the importance of flooded pastures; when vast areas of Holland were inundated for military purposes during the last war, adult pike moved on to them and dense populations of young fish were subsequently observed during the summer. In Irish investigations in 1965 (Kennedy, unpublished data) spawning took place in depths of 15 to 30 inches of water in shallow situations on bottoms consisting of broken reed mats (Phragmites) on mud (L. Arrow); Agrostis stolonifera; and Juncus bulbosus var. fluitans mixed with a little Mentha, Hippuris and other weeds (L. Mask, L. Corrib); and Fontinalis (L. Sheelin).

3.1.8 Egg

The diameter of the egg ranges from 2.3 - 2.4 mm before fertilization and 2.6 - 2.7 mm afterwards; one litre of ova contains on the average 65,000 eggs. The mature eggs are relatively transparent, or irregularly spherical in shape in different shades of yellow-brownish colour, with a distinct spot of orange yolk (Zawisza, 1963). They are not laid in densities greater than 60 per square metre, are slightly adhesive and sink after extrusion. Carbine (1954) gives egg size as 2.3 - 3.4 mm and Franklin and Smith (1963) as 2.4 - 3.0 mm. Frost and Kipling (1964) give the mean diameter of the unfertilized egg as 2.3 mm and 2.8 mm when fertilized. In Irish investigations from 1959-65 (Kennedy, unpublished) pike eggs were both collected in the field and stripped artificially; fertilised eggs were golden to honey coloured, translucent with a moderate perivitelline space containing large numbers of minute oil globules distributed in big clusters. Eggs artificially fertilized in Lough Sheelin in March 1954, were 3.0 mm in diameter; in Lough Mask 2.8 -3.0 mm and in Lough Owel in April 1954 the diameter was 2.75 mm. Eggs collected in the field gave corresponding measurements.

3.2 Larval history

3.2.1 Account of embryonic and juvenile life (prelarva, larva, postlarva, juvenile)

- Feeding

Kostomarova (1959) says that active feeding starts before resorption of yolk sac. Starvation occurs if young fish are totally dependent on yolk sac food supply. Active feeding starts 9-10 days after hatching when larvae are 12.5 - 13.0 mm long. Frost (1954) reports that pike 10.5 - 17.5 mm in length feed on entomostraca. At 35 - 200 mm their food consists of perch (Perca fluviatilis) fry 10 - 60 mm long, aquatic insect larvae and Eurycercus lamellatus. Hunt and Carbine (1951) state that the young begin to feed at lengths of 11 or 12 mm on entomostraca and then on insects and vertebrates; at about 50 mm they are as piscivorous as adults. Carbine (1938) and Pearse (1918) both say that small pike take small crustaceans and insects which are replaced by fish by the larger pike. Copland (1956) records the food of pike as consisting of Asellus, chironomid and mosquito larvae and copepods. Healy (1956) records finding Asellus, Gammarus Pisidium, Gasterosteus aculeatus and Perca fluviatilis (fry) in the stomachs of pike of the 20-25 cm group. McCarraher (1959) found that the growth of fingerlings was better in phyllopod shrimp habitats than in waters in which these invertebrates did not occur. Nikolsky (1963) says that when in young pike the amount of energy expended on the capture of crustaceans starts to exceed their calorific value, the pike start to feed on young fish. If the pike is kept on a diet of planktonic crustaceans, it gradually ceases to grow, and eventually dies. Clark (personal communication) says that, at St. Mary's Fish Farm, Ohio, pike up to at least 12.7 cm long would feed on small crayfish (Orconectes). He considers that, by eliminating fishes from the diet and forcing the pike to feed solely on the young crayfish, a greatly increased pond production has been obtained. He also reports that when very young pike were fed on Daphnia magna the crustaceans lodged in their throats and killed them.

- Rates of development and survival

The embryonic phase, i.e. from fertilization to hatching, lasts on the average three weeks. The length of the larva immediately after hatching ranges from 6.5 - 7.5 mm. Resorption of yolk sac takes 5 - 10 days. During this period the fry is attached to plants or lying on the bottom. (Zawisza, 1963). Schaperclaus (1961) gives the length of the newly hatched larvae as 8.5 to 9.0 mm and Huet (1960) as 8.0 to 9.0 mm. Price (1957) states that the period from egg cleavage to pre-hatching stage is 11 days, and gives the following schedule:

Stage	Temp (°C)	Day
Cleavage	5.5 - 7.7	First
Blastula	5.5 - 7.2	Second
Early blastoderm	4.4 - 5.5	Third
Germ-ring	3.3 - 7.7	Fourth
Early embryonic shield	5.5 - 7.7	Fifth
Germ-ring equatorial stage	7.7 - 11.1	Sixth
First fish-like appearance	12.7	Seventh
"Eyed egg"	10.0 - 12.2	Eighth
Heart beat	11.6 - 12.7	Ninth
Complete circle of embryo	12.2 - 8.8	Tenth
Pre-hatching	8.8 - 8.8	Eleventh
Hatching	7.2 - 8.3	-

For the development from the advanced fertilized egg stage to the free-swimming stage see Figures 3 and 4 taken from Gihr (1958). The embryological development of the adhesive organ is described in detail by Georges (1964).

Shampardina (1957) records a peak in oxygen consumption per gram of embryo at the end of the yolk sac phase of development. Genina, Martinson and Redikson (1948) say that incubation lasted about 8 days at a

water temperature of 12 - 13°C under artificial propagation conditions. Franklin and Smith (1960) record that critical survival stages in embryonic development were (a) between fertilization and closure of the blastopore and (b) between hatching and end of alevin stage, mortality being due to toxic iron compounds or excessively rapid temperature changes. Survival of fingerlings is greatest when water levels remain stable. Loss of fry between 9 - 13 mm and 15 - 21 mm was 26.8 percent. The same authors (1963) report that at Lake George, Minnesota, 63.6 percent and 96.6 percent of pike embryos survived in the years 1955, 1956 and 1957 respectively. Dobie (personal communication) says that embryo survival is usually high under natural conditions. Monten (1948) reports loss of eggs on spawning grounds in Lake Straken, Sweden, to be 95 - 98 percent and mortality of eggs and fry which had reached a length of 9 - 13 mm as being 99.1 percent. Clark and Now (1955) found that egg losses occurred due to their being settled on by colonies of Vorticella. Carbine (1964) gives the following survival rates for Michigan: 0.07, 0.04 and 0.44 percent.

- Parental care

None

- Predators on young fish

Yellow perch, dragon fly and damsel fly nymphs, beetles larvae, water bugs, water birds and snapping turtles (Carbine, 1938). Other pike formed from 25 - 32.2 percent of the vertebrate food of pike from 21 - 30 mm in 1939 (Hunt and Carbine, 1951). The pressure of predation on pike of over 40 cm long is unimportant. Predators on pike under this length are perch, pike-perch and pike. The grey heron, Ardea cinerea and the cormorant, Phalacrocorax carbo, the grebe, Podiceps lath and the diver, Colymbus sp. are bird predators and the otter, Lutra lutra is a mammalian one (Zawisza; personal communication). Fabricius (personal communication) says that the osprey is a common predator in Sweden, Norway, Finland, northern parts of the Soviet Union and in Canada and the U.S.A. Monten (1950) says that larval dytiscid beetles are important predators, and that the high mortality of pike eggs is caused by "Spawn enemies". Minnows (Pimephalus promelas or P. notatus?) and perch (Perca flavescens) were responsible for a reduction in the number of fry migrating from the spawning ditches to Houghton Lake, Michigan (Carbine, 1942). In artificial propagation in Ohio losses amongst fry occurred when they came in contact with Hydra on the mesh of baskets in troughs. This was remedied by flushing through baskets with a 3 percent salt solution (Clark, personal communication). For more information on the egg, larval and juvenile stages under hatchery conditions see 5.6.

3.3 Adult history

3.3.1 Longevity, life expectation

Fifteen years in the Lower Saskatchewan River (Rawson, 1932), 25 years in Upper Saskatchewan River (Miller and Kennedy, 1948), 14 years in Wisconsin (Van Engel, 1940).

Life expectation: For Lake Windermere, Frost and Kipling (1964) say that 17 years is the expected maximum; Solman (1945) 3 - 5 years in the Lower Saskatchewan River; Miller and Kennedy (1948) 5 - 6 years in Upper Saskatchewan River; Carbine (1938) 3 - 4 years in Michigan; Nelson, Merlin and Hasler (1942) 3 years in Wisconsin; Clark (1957) 3 - 4 years in Ohio. Bennett (1962) gives the life span as between 16 and 17 years in Northern Wisconsin.

3.3.2 Hardiness

Lawler (1960) gives the following instance of the hardiness of the pike: "15 - 20 minutes after capture by gill net a 'silver' pike was replaced in fresh water and revived. A day later it was weighed, measured, etc. and the small intestine was removed through a 4 cm long cut in the abdominal wall; the fish was left lying on a wet table for about 20 minutes and, as it still showed signs of life, was put in an aquarium where it began to swim. The incision was then sutured and the fish continued to live for a total of thirty days from the time the intestine was removed and apparently took no food in all that time". Lawler (1964) quotes other examples of the hardiness of this mutant and suggests that it is superior to the normal pike in this respect.

3.3.3 Competitors

The pike competes with and largely displaces the muskellunge where their ranges overlap; it competes also to some extent with large bass and wall-eye (Johnson, 1949). It must also compete with the other piscivorous birds, fishes and mammals mentioned above as preying on the young pike.

3.3.4 Predators

Zawisza (1963) says that predation on large pike is unimportant. This is probably true but Hubley (1961) reports fishing scars of Ichthyomyzon unicuspis and I. castansus on pike in the Upper Mississippi River. Nikolsky (1963) says that the pike form 6.1 percent of the food of cormorants on the

Volga Delta. The birds already mentioned, as well as the otter, also prey to some extent on the older pike.

3.3.5 Parasites and diseases

U.S.S.R. and Europe
Cestoda: Proteocephalus cernua; Diphyllobothrium latum; Triaenophorus nodulosus; T. Crassus.
Trematoda: Phyllodistomum folium; Eucephalus polymorphys; Clinostomum complanum; Mesostephanus appendiculatus; Paracoenognimum ovatus; Azygii lucii.
Nematoda: Philometra obturans; Camallanus lacustris; Rhaphidascaris canadensis.
Acanthocephala: Acanthocephalus lucii; Echinorhynchus clavula; Pomphorhynchus laevis.
Protozoa: Myxidium lieberkhuni; Henneguya zschokkei, H. psorospermica and H. schyura; Chloromyxum esocinum (Parasitology of Fishes, 1958)
Ophistoreis felineus (Marita, 1959).
Cestoda: Triaenophorus nodulosus; plerocercoids on liver of fry and older specimens; adult form in intestine, T. crassus, rare. Diphyllobothrium latum; plerocercoids in muscle; rare. Proteocephalus esocis; rare.
Trematoda: Eucephalus polymorphus; common in intestine. Riphidocotyle illinse, Phyllodistomum folium; common on urethra and vesicle. Azygia lucii; very common in stomach. Allocreadium isosporum; in intestine; rare. Sphaerostomum bramae; in intestine; rare. Diplostomum clavatum; very common; frequently abundant on eye. D. spathaceum; in eye; common. Paracoenognimum viviparae; metacercariae in muscle.
Nematoda: Raphidascaris acus; common. Camallanus lacustris; common.
Acanthocephala: Neoechinorhynchus truttae; rare. N. rutili; common on cyprynids, rare on pike. Echinorhynchus truttae; rare. Acanthocephalus lucii; common; sporadic. Corynosoma strumosum; sporadic.
Protoza: Myxidium lieberkhuni; common on urethra and vesica. Henneguya lobosa; frequently very common on gills. H. psorospermica; on gills. H. oviperda; on ovary; decreases fecundity. Chilodonella cyprini; on gills; not rare on pike. Trichodina domerquei; common on gills and skin. T. epizootica; on gills.
Crustaceae: Ergasilus siebaldi; common and frequently abundant on gills. Lernea esocina; on gills and skin; rare. Argulus foliaceous; on skin; common and dangerous to fry (Grabda, 1963).

Cestoda: Triaenophorus nodulosus.
Acanthocephala: Acanthocephalus lucii (Copland, 1936).
Cestoda: Proteocephalus sp; Triaenophorus nodulosus (plerocercoid stage); Cucullanus truttae.
Acanthocephala: Echinorhynchus clavula; Neoechinorhynchus rutili.
Trematoda: Tetraonchus momenteron.
Protozoa: Henneguya psorospermica (Chubb, 1963).

U.S.A. and Canada
Cestoda: Proteocephalus pinquis and P. stizotheti. Contracaecum brachyurum.
Acanthocephala: Leptorhynchoides thecatus (Worley and Bangham, 1952).
Cestoda: Proteocephalus ambloplites; Dibothriocephalus latus; Paraclon sp.
Protozoa: Corynebacterium sp. (Ridenhour, 1957).
Protozoa: Cryptobia gurneyorum (Laird, 1961).
Cestoda: Proteocephalus ambloplites.
Trematoda: Phyllodistomum sp.
Nematoda: Spintectus carolini and S. gracilis.
Hirudinea: Illinobdella sp.
Protozoa: Macroderoides flavus; Trichodina sp., Cryptognimum chyli (Fischthal, 1947).
Cestoda: Triaenophorus nodulosus.
Trematoda: Crepidistomum cooperii. Azygia augusticauda; Grodactyloideae; Haplonema sp; Neascus sp.
Nematoda: Contracaecum brachyurum; Spinitectus gracilis.
Acanthocephala: Leptorhynchoides thecatus (Bangham, 1946).
Cestoda: Proteocephalus ambloplites (Meyer, 1954).
Cestoda: Proteocephalus pinquis;
Acanthocephala: Neoechinorhynchus tenellus (Bangham and Hunter, 1939).
Bacteria: Aeromonas salmonicida; first apparently natural infection of pike described (Economon, 1960).

Otterstrøm (1928 and 1927-28) suggests that the pike pest (Hechtpest, Geddespesten) may be caused by such pathogens as Bacterium pestis astaci: the flat characteristic ulcers are regarded as primary symptoms and other pathogens may develop on these, causing other secondary symptoms. The disease may be conveyed to other pike by leeches (Piscicola) or by parasitic copepods.

Mulcahy (1963) reports the occurrence of lymphosarcoma in 13 pike; histological sections showed that tumours were in all cases lymphosarcomas.

Steffens (1961) reports damage on fins; Wunder (1960) describes body defects and discusses causes; control measures are suggested. He also (1961) describes mass occurrences of jaw, gill cover, fin and pigmentation abnormalities and suggests that they are due to vitamin deficiencies.

- Miscellaneous

Control of leech infestation (Avdos'ev et al, 1962): fresh Cu SO4 solution of 0.4 - 0.5 mg per litre, clarified by ammonia was highly effective in clearing up leech infestation in ponds.

3.3.6 Greatest size

A pike of 24.09 kg is reported by Anon (1957); one of 20.9 kg was taken in 1957 (Inl. Fish.Trust, 1958). This fish was about 16 years old. Van Engel (1940) records a fish 133.6 cm long weighing 20.9 kg from Wisconsin and Berg (1962) mentions an apparently authentic weight of 34 kg for a pike taken in the Lower Dnieper.

3.4 Nutrition and growth

3.4.1 Feeding (time, place, manner, season)

Pike generally feed in daytime and all the year round wherever food is to be found. Frost (1954) found that the lowest rate of feeding occurred in March and April, probably indicative of the existence of a spawning fast; Healy (1956) and Fedin (1958) maintain that there is no such fast. Nikolsky (1963) says that the main organs by which the pike orients towards its prey are the lateral line and the eyes. The first orientation towards its moving prey occurs through the lateral line while the eyes provide a correction when the pike darts at the prey. If the eyes are extirpated the pike can still feed, orienting itself.....by means of the lateral line. Wunder (1927) and Hoogland and Tinbergen (1956) describe in detail manner of capture and manipulation of the prey before swallowing.

Clark (personal communication) suggests that pike in Ohio grow fast during the hot months of June, July and August. Net and sport catches are negligible then when water temperature of 75° - 80°F. (24° - 26.7°C) prevail. Aquarium fishes did not feed at such temperatures either. Over 100 stomachs of wild fish taken in these months contained no food remains. Feeding, he suggests, is resumed when temperatures drop to about 70°F (21°C).

Johnson (in press) calculated the maintenance and growth requirements of 0+ and 1+ pike kept in tanks at the Freshwater Biological Association Laboratory, Windermere. He found that the consumption of food for growth and maintenance in pike indicates a more efficient converter than in some other fish species, including Salmo trutta.

Seaburg and Moyle (1964) report that during the summer of 1957 the average volume of food in the stomachs of pike from Grove Lake, Minnesota, was 4.4 ml and from Maple Lake, Minnesota was 2.0 ml. It was noted that the percentage of empty stomachs in Maple Lake pike increased from 48 percent in May to 77 percent in July. This increase was associated with a decrease of the percentage of perch in the stomachs.

3.4.2 Food (type, volume)

Pike eat almost anything that comes their way. In the carnivorous sense they are omnivorous. Larsen (1951) states that in spring the diet consisted mainly of bottom invertebrates, especially Gammarus sp; fish were the smaller part of the diet and of the fish species found in the stomachs, trout were the most numerous. Lawler (1960) describing the food of the 'silver' pike (see Mutants, 1.3.1) says it is the same as that of the ordinary fish, as follows: Perca flavescens, Catostomus commersoni, Notropis hudsonius, Pungitis pungitis and Percopsis omiscomaycus. Ivanova (1960) says that the food of adult pike consists of fish of little value such as roach, perch and ruff. Vaschenko (1961) reports that the pike is a dangerous predator on carp where they occur together and must be rigidly controlled; otherwise it is beneficial, eating fish of no value. Frost (1954): for pike of 20 - 105 cm the food was Perca fluviatilis, Salmo trutta, Salvelinus sp., Gasterosteus aculeatus, Phoxinus phoxinus, pike and eels, in that order of importance. Perch dominate in May-October, trout in October - February and char in November and December. The feeding habits of pike have a marked effect on the survival of fish in Windermere. Lawler (1956) estimates that about 1,500,000 water fowl on the average are destroyed annually by pike on a wild life refuge in Michigan though fish and crayfish are the main food. Munro (1957) describes a pike population that lived almost entirely on invertebrates; frogs and smaller fish of their own species were the main food of the older pike. Healy (1956) found that the diet of the larger fish was almost exclusively piscivorous. Seaburg and Moyle (1964) say that fish made up 100 percent of the food of pike in Maple and Grove Lakes in 1957, perch (Perca flavescens) predominant. Dobie (unpublished) reports that fish made up 90.3 percent of the food eaten by pike in Lake Vermillion, Minnesota, while insects

amounted to 3.6 percent and unidentified material came to 5.7 percent.

Both Frost (1954) and Healy (1956) found that seasonal abundance appeared to be the factor responsible for the type of food eaten and not choice. Toner (unpublished data) found seasonal distinction between the two principal fodder fish; perch (Perca fluviatilis) were more frequently eaten in the late spring and summer and brown trout (Salmo trutta) were more popular in the autumn, winter and early spring months. Nikolsky (1963) states the size of the prey taken increases with the size of the pike. Scholz (1962) obtained the following daily intake figures for young pike, expressed as percentages of their body weights: Fish 3 - 5 percent; Cyclops, 13 - 14 percent; Oligochaetes 3 - 4 percent; Chironomid larvae 4 - 6 percent; Gammarus 11 - 12 percent; he also observed that 1- to 2- summer old pike preferred morsels of between 10 and 20 percent of their own body weight, the largest morsels swallowed and digested being 30.7 percent of the body weight. Hoogland and Tinberg (1956) say that the optimal size of food morsel was between third and half the size of the pike. Toner (1959) estimated that 2,594 pike in two lakes ate approximately 112.5 tons of brown trout as well as a rather smaller amount of perch in one year.

3.4.3 Relative and absolute growth patterns and rates

Variations in growth rate are illustrated graphically in Figure 2 and are given below in tabular form. The reference to the curves in Figure 2 are as follows:- Spain (Calderon-Andreau, 1955); Ireland (Healy, 1956; data for two lakes); Wisconsin (Van Engel, 1940); Denmark (Dahl, 1963); Scotland (Munro, 1957).

Scale formation in relation to the length and age of the young fish is discussed by Wydallis (1960). She concludes that length seems to be more the determining factor than age in scale development. This starts on and immediately above and below the lateral line in the area below the posterior half of the dorsal fin and develops more rapidly anteriorly and ventrally than posteriorly and dorsally. She suggests that for this reason scales for age determination should be taken from the part of the body where they are first laid down.

3.4.4 Relation of growth to feeding etc.

Clark and Now (1955) say that a pike needs between 5 and 6 pounds to make one lb increase in body weight.

Table V
Length in cm for age in years

Age group	(Dahl, 1963) Denmark		(Healy, 1956) Ireland		(Van Engel, 1940) Wisconsin	(Miller and Kennedy, 1948) Northern Canada	(Munro, 1957) Scotland
	Brackish water	Freshwater	L. Rea	L. Barnagrow			
1	16.5	8.5	25.9	18.2	49.5	9.4	7.7
2	33.3	15.0	45.1	29.3	54.6	15.2	18.8
3	49.5	20.5	60.1	39.6	59.4	23.4	29.9
4	61.1	29.0	72.2	49.8	68.6	31.5	38.2
5	72.5	38.0	84.3	58.4	73.4	38.9	44.6
6	78.5	44.0	94.4	63.6	80.3	44.9	50.0
7	84.0	50.5	102.6	70.0	88.9	50.8	53.2
8	89.5	54.5	104.2	86.8	94.7	56.4	57.6
9	96.0	59.0	-	-	100.6	61.2	-
10	101.5	-	-	-	112.5	65.8	-
11	106.0	-	-	-	113.8	70.1	-
12	108.0	-	-	-	-	-	-

Differential growth rate of the sexes: Solman (1945), Carbine and Applegate (1946) noted that females grew faster than males, Healy (1956) that the difference in growth rate was slight in young fish but as they grew older the female rate of growth was more rapid than that of the male. Miller and Kennedy (1948) found that though females lived longer than males they were no larger age for age. (Frost and Kipling, 1959).

Table VI
Growth (in cm) of females and males in Lake Windermere

Year	Females	Males
1	23	23
2	40	40
3	55	52
4	64	59
5	70	63
6	76	65
7	80	66
8	84	68
9	88	69
10	90	70
11	93	72
12	96	-

Scales are commonly used both for age determination and back-calculation of growth rates. Healy (1956), Munro (1957) and others, but Frost and Kipling (1959) found that for Windermere pike the body-scale relationship was allometric and that ill-defined annuli may lead to erroneous results in back-calculating length for age. They found that opercular bones were more satisfactory for this purpose and devised a method involving the use of Walford plots to overcome the difficulty caused by the thickening of the centre of the bone which may obscure the first ring. In general they found that a straight line was obtained when "length at age n" was plotted against "length at age n plus 1", suggesting that the successive yearly length increments decrease in magnitude in geometric progression.

Wydallis (1960) says that since the earliest developed body scales are those dorsally and ventrally adjacent to the lateral line below the posterior half of the dorsal fin, scale samples for age determination from these regions would probably give most accurate results.

Franklin and Smith (1961) have analysed allometric growth in pike of 25 - 115 mm long; Healy (1956) found that back calculations of lengths made from scales corresponded with the measured lengths of fish of the same age. For a detailed description of the scale reading method and technique see Williams (1955).

3.4.5 Physiology

Table VII
Chemical composition of scales in percentage by weight (Van Oosten, 1960)

Ash in dry matter:	40.44	$Ca_3(PO_4)_2$:	52.25
$Mg(PO_4)_2$:	5.01	$CaCO_3$:	41.73
CaO:	21.93	MgO:	0.51
P_2O_5:	18.00	CO_2:	2.30

- Corpus cerebelli

Karamian (1949) found that removal of the corpus cerebelli disturbed equilibrium, locomotion and sensory functions.

- Medulla oblongata

Fluorens (1957) cut the medulla oblongata on one side and found that the operculum on that side stopped moving; a cut in the middle of the medulla caused both operculars to stop.

- Eye

Walls (1942): the cornea of the eye is yellow and acts as a light filter. There are up to 56,200 visual cells in the eye; the proportion of rods to cones is 1:9.

- Olfactory mechanism

Pipping (1927): water is deflected through a capsule as the pike moves through the water.

- Carotenoids

Taxasanthin is contained in the skin (Fox, 1957).

- Digestion, enzymes

Vonk (1927) gives the mean value of the pH in the pike's stomach as between 4.5 and 4.7; Vonk (1939) and Vonk and Mennega (1938) showed that though the pH on the surface of the food mass was 2.4 - 3.6 it was 4.7 mm towards the centre of the mass. Vonk (1941): a pepsin is present in the pike with a pH optimum of about 2, similar to that found in Acanthias, the frog, Testudo and the pig.

- Pepsin

Pike pepsin is more thermolabile than that of mammals and its trypsin activity is eight times greater than that of the carp (Vonk, 1939 and 1941).

- Adrenaline

Gill vessels are dilated at concentrations of 10 - 6 (Krawkow, 1913).

- Fat content

Nikolsky (1963): the fat content is 0.5 percent; it changes very little throughout the year owing to short intervals between feeding.

- Gas

The air bladder contains about 19 percent of oxygen (Nikolsky, 1963).

- Salinity

Dahl (1961): salinity of 18 promill killed pike. In the Baltic, pike can live at salinities of up to 10 promill and breed at salinities of up to 7 promill (Svärdson, 1964).

- Ultra-violet light

Lubitskaia and Dorofeeva (1961); brief exposure of fertilised eggs to UV. rays (588 ergs 1 minute/1mm^2) had a significant effect on survival of developing embryos and caused a decrease in the amount of metamerism; the caudal nodule was the most sensitive part.

- Electric current

An 0.5 - 5.0 volt current stimulates contraction of the isolated pike heart when the positive electrode is on the auricle and the negative is on the bulbus arteriosus. Reversing the electrode positions decreases heart beat (Acolat, 1955).

- Haemoglobin

Korzhuev (1958) gives haemoglobin concentration as 7.9 g and the content per kg of body weight as 1.5 g.

3.5 Behaviour

Johnson (1960) has made observations on behaviour (feeding, aggression, etc.) of pike fry.

3.5.1 Migration and local movement

None, apart from widespread spawning movement in the spring (Miller, 1950). Carlander and Ridenhour (1955) report that stocked tagged pike of 26.6 - 40.6 cm in length moved to all parts of a lake 1,475 ha in area within six months, even when planted out at one end of the lake. Clark (1958): Adults showed relatively little movement except under unusual circumstances. Wistrom, Apelgren and Threinen (1957) say that after spawning the pike becomes solitary and almost territorial.

3.5.3 Reproductive habits

No spawning territories maintained and aggressive behaviour limited to threat posture. Males seem to prefer the larger females. Spawning groups formed of usually 2 - 3 males to one female, but in small tanks one male becomes dominant. The spawning consists of a long series of mating acts at short intervals separated by periods of rest. In tanks the average number of acts per minute was 1.5 - 2.6 at water temperature of 18°C and 1.7 per minute, in the field at 12°C. These observations confirm many of Svärdson's (1948 and 1949). At sunset spawning ceases and the pike retreat to deeper water (Fabricious and Gustafson, 1958).

4 POPULATION (STOCK)

4.1 Structure

4.1.1 Sex ratio

Rawson (1932): males and females about equal in spawning runs. Solman (1945) says that 47.8 percent were females; Carbine (1938) says the sexes were represented in the proportion of 6 males to 4 females. Healy (1956) found that 52.0 percent of the stock examined consisted of males with annual variations of 27.0 - 63.0 percent males and 37.0 - 73.0 percent females. Toner (unpublished): the sex ratio of 5,320 pike examined over 3 years (1961 - 1963) varied as follows:-

Year	1961	1962	1963	Overall
Males	44.6%	42.3%	49.4%	46.2%
Females	55.4%	57.7%	50.6%	53.8%

4.1.2 Age composition

Table VIII
Age distribution of pike in Loch Choin (Munro, 1957)

Years	Percent
0	76.8
1	12.7
2	5.6
3	1.2
4	0.5
5	0.4
6	0.9
7	0.6
8	0.1
9	-
10	-
11	-
12	0.5

Healy (1956) records that one year class predominated in Lake Glore from July 1951 to May 1954 except in May 1953.

4.1.3 Size composition

Munro (1957) gives length frequency distributions: pike ranging from 9.1 - 96.0 cm were collected after Loch Choin was poisoned. Healy (1956) found that one length group predominated in monthly samples and that new length groups appeared frequently. The fish referred to at 4.1.1 above (Toner, unpublished) varied in length from 12.7 - 124.5 cm. Zawisza (1963): the size composition of the commercial catch in Poland (see 5.4.3) was as follows: 52 percent from 1 - 3 kg; 25 percent from 0.5 - 1.0 kg; 23 percent less than 0.5 kg and greater than 3.0 kg.

4.2 Size and density

4.2.1 Average size

Carlander (1955) gives estimates of average standing crop figures for 59 game fish lakes as 9.55 kg per ha. with a maximum of 22.4 kg per ha.; the average for 30 coarse fish waters (non game) was 6.05 kg per ha. Wistrom, Apelgren and Threinen (1957) say that standing crops of 22.45 kg per ha. are the general order; Solman (1945) gives a figure of 66 pike per ha. for the Lower Saskatchewan River. Munro (1957) recovered 2,078 pike weighing 141.2 kg from L. Choin (26 ha.) and Twomey (1960) counted 110 weighing 23.63 kg from a 1 hectare lake after poisoning. A preliminary estimate by Frost and Kipling (1964) for water of less than 10 metres deep gives about 8 kg per hectare of pike aged 2 plus and over. Seaburg and Moyle (1964) report a standing crop of 29.4 fish, of 14 inches (3515 cm) per hectare in Maple Lake in Minnesota in 1957 and of 46.4 fish per ha. in Grove Lake, Minnesota in 1958. Dobie (personal communication) says that Scidmore (unpublished manuscript, 1964) found a population of 17 fish with a total weight of 12.4 kg per ha. in Grace Lake.

4.3 Natality and recruitment

4.3.1 Natality

Franklin and Smith (1963) concluded that there is no direct relationship between adult abundance and the strength of resulting year classes.

4.4 Mortality, morbidity

4.4.2 Factors or conditions affecting mortality

Woodbury (1942) reported a mortality of pike due to oxygen levels of 30 - 32 ppm at the surface of Lake Waubesa (Wisconsin). This oxygen deficiency was produced by a bloom of Chlamydomonas and the deaths were attributed to the formation of gas emboli in the gill capillaries which blocked circulation.

4.5 Dynamics of population

Frost and Kipling (personal communication) are working on population numbers, biomass, natural and fishing mortalities on data from Windermere collected over the past 20 years. They also report that a study of the pike's predation on other fish species in Windermere, by means of mathematical techniques is in progress.

5 EXPLOITATION

The pike is fished both for food (commercial) and for sport in most European countries and in the U.S.A. and Canada; no commercial fishery exists in Great Britain or Ireland where it is not generally regarded with favour as a table fish, but it is fished for sport in these countries.

5.1 Fishing equipment

5.1.1 Fishing gear

Pike are caught commercially by means of gill nets, seines, and traps; sport fishing is by spinning, by trolling and by fishing with live baits (Van Drimmelen, personal communication).

5.2 Fishing areas

5.2.1 General geographic distribution

Fishing is carried on practically throughout the range of the distribution of the pike. An important fishery exists in the brackish waters along the Swedish coasts (Alm, 1957). The best fishing grounds in the Netherlands are the relatively small and shallow canals and polder waters (Van Drimmelen, 1952 and 1953).

5.3 Fishing seasons

5.3.1 General pattern of fishing season

Year round in most cases but many countries, Britain for example, enforces a closed season for sport fishing. Many of the American States also regulate the season for both sport and commercial fishing.

5.4 Fishing operations and results

5.4.2 Selectivity

Bennett (1962) says that only pike of 16 - 18 inches (40 - 45 cm) are acceptable to sport fishermen.

5.4.3 Catches

Some data (in metric tons) available to the author are given below:

Lakes Huron, Michigan and Eire - 58.8 in 1951 (Anderson and Peterson, 1953). The pike is an important commercial species in northern Canadian water.

U.S.A. - 106.8 average annual for six years (1952 - 1957); value: 135,000 dollars; 4 percent of the catch made up of *E. niger* (Van Oosten, 1960).

Netherlands - annual commercial catch in 1920's was 500 - 600, recently 150 - 200. Sport fishermen's catches are probably greater to-day. Yields vary from a few kg to 20 - 30 kg per ha. per year (Van Drimmelen, 1952; 1953).

Poland - 600 - 780 per annum (Zawisza, 1963).

5.6 Fish farming, transplanting and other intervention

- Propagation

Artificial propagation is widely practised in Europe and America with subsequent stocking of either natural waters or ponds for sport fishing or for food. Genina, Martinson and Redikson (1958) and Kostomorova (1959) give details for the U.S.S.R. Van Drimmelen (1964) describes techniques for hatching of 20 - 40,000,000 ova from wild fish; the use of filtered water, he found, increased the yield from 20 percent in 1958 to 78 percent in 1959. Pond yield averaged 35,000 fry per acre in 1959 and 1960. Huet and Timmermans (1958) give their methods of raising seven weeks old fish. Zawisza (1963) says that though up to 10 million fry were stocked annually by State enterprises in rivers and lakes in Poland over a seven year period and 10 - 15 million by other fishery organisations no apparent beneficial effects resulted and the intensity of stocking has since dropped; the rearing of fry in ponds is carried on to a limited extent only.

In the U.S.A. efforts are being made to preserve marshes and wet land from drainage, so as to maintain spawning grounds. Between 1952 and 1962, in Minnesota, 26 suitable sites of total area 452.4 ha have been preserved by purchase or option. 13 of these have been improved by the construction of water level control dams, dykes and other works. Five other areas are also being purchased.

Breeders introduced into ponds in South Dakota have produced crops ranging from 536 - 689 fingerlings per acre which reached the length of seven inches. Ohio's crops from natural reproduction in such ponds have ranged from 138 - 1,247 fish per acre, 3 - 5 inches in length (Clark, personal communication).

- Feeding

Schumann (1963) describes a method of capturing very young perch for feeding hatchery reared fry by means of light from a propane gas lamp. Van Drimmelen (1963):

zooplankton is collected by specially adapted boat and fed to fry in hatcheries. In north-central Nebraska (McCarraher, 1950) several ponds of 5 acres or larger have been stocked with a northern pike-bluegill combination. The pike were released as fingerlings and the bluegill as adults so that they furnished young bluegills for pike forage during the first season.

- Transplanting, extension of range

McCarraher (1961): pike have been planted in several Canadian States in which they were not indigenous and plantings are extending the range to the waters of south and west Canada. Calderon-Andreau (1955) describes the introduction of the pike to Spain and Lopes (1963) reports that in spite of existing barrages some pike have lately been caught in Portugal in the Guardiana River close to the Spanish border. Went (1957) produces strong evidence in support of the belief that the pike is not native to Ireland but is an introduced fish.

Threinen and Oehmcke (1950): the pike, introduced into new areas, is usually displacing the muskellunge (E. masquinongy).

Clark (personal communication) reports that pike have been shipped from Ohio to Kentucky and North Carolina. The results of these experiments are not known to this author.

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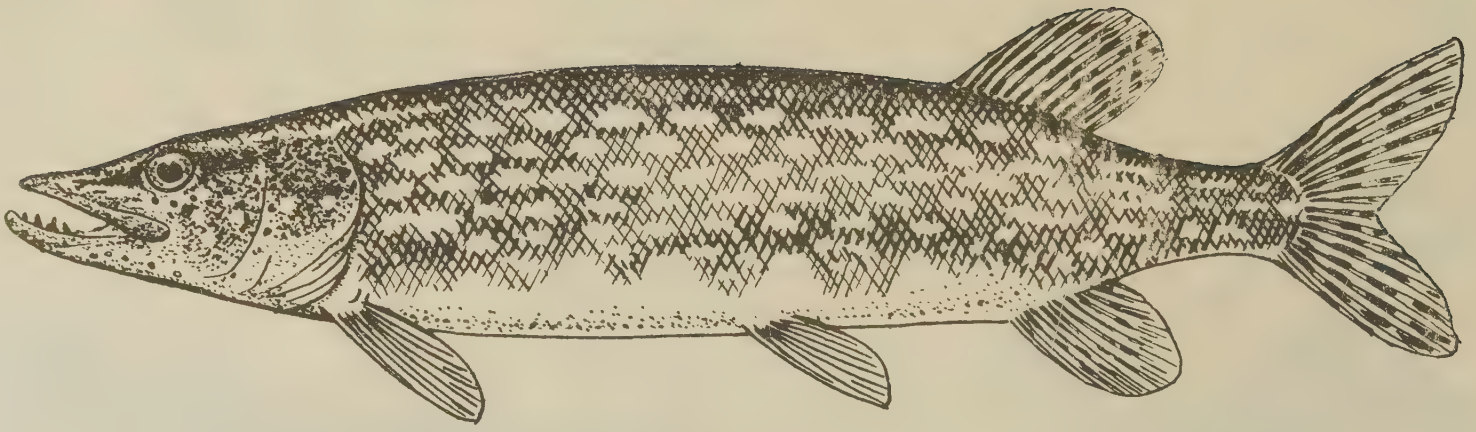


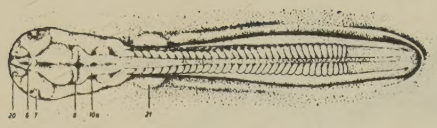
Figure 1. Esox Lucius Linnaeus
(Drawn by Dr. Michael Kennedy)

Figure 2

Distribution of Esox lucius and the Esocidae generally.

Figure 3

a



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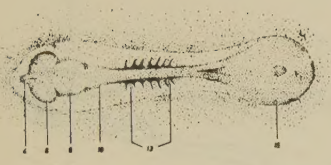

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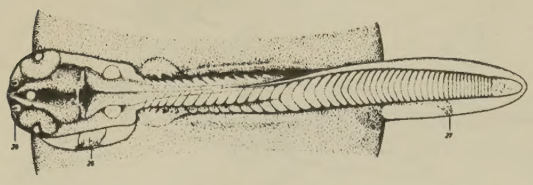

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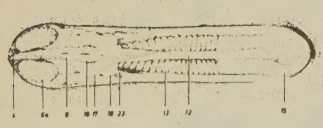

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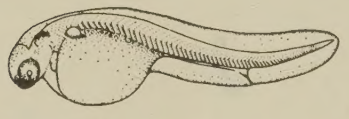

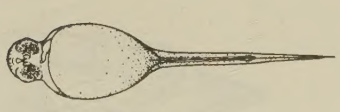

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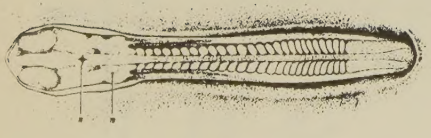

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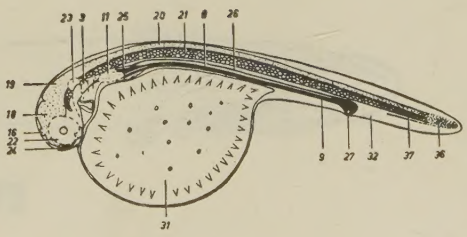
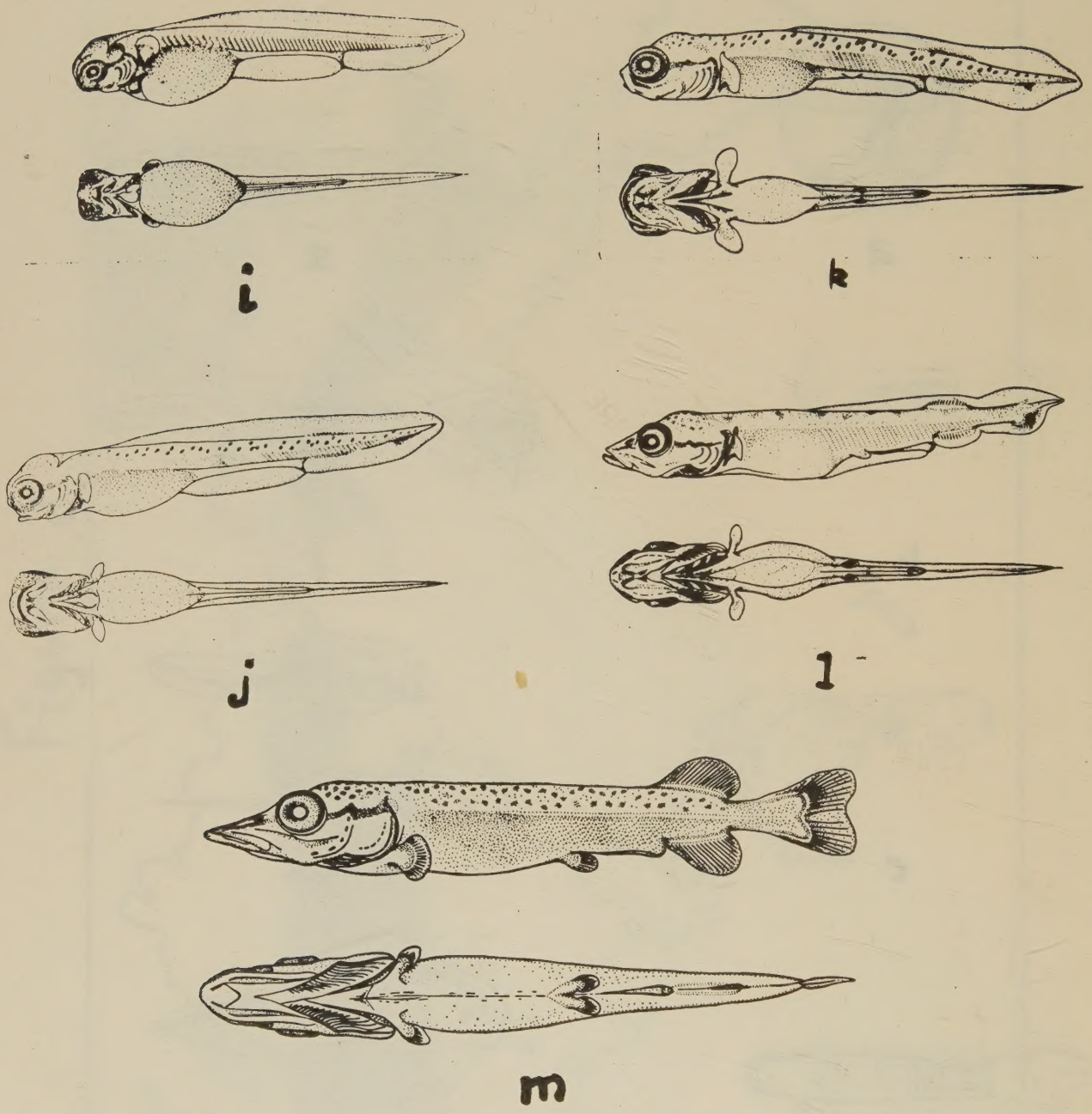


h

Development from advanced fertilized egg to advanced yolk sac stage.

1. Chorion; 2. Space between chorion and 3 the yolk; 4. Forebrain; 4a. Cerebral plate; 5. Pineal body; 6. Eyes; 6a. Optic cups; 8, 9, 10 and 10a. Various parts of brain; 13. First muscle segments; 15. Tail; 17 and 18. Branchiae; 19. Otocyst; 20. Olfactory capsules; 21. Pectoral fins; 22. Eye; 24. Olfactory organs; 27. Embryonic rectum and urinary organs.

Figure 4



Transition from late yolk sac stage to free swimming fry.

Figure 5

Growth rate of pike in different countries.
Curves have been smoothed and chosen to show major differences;
they are not necessarily typical of the country of origin.